The Effectiveness of the Aquaflex Gel Pad in the Transmission of Acoustic Energy

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Objective: The purpose of this study was to assess the effectiveness of the Aquaflex Gel Pad in the transmission of acoustic energy.

Design and Setting: This was a comparative study that utilized descriptive statistics for result interpretation. The independent variables included ultrasound intensity, interposed materials, and trials. The dependent variable was peak-to-peak voltage output recorded via an oscilloscope. The study was conducted in a ventilated research laboratory.

Measurements: Three trials were conducted with six combinations of material interposed between a conducting (1 MHz) and a receiving sound head. The interposed materials were as follows: 1) ultrasound gel, 2) gel plus a gel pad, 3) gel plus a gel pad and pig tissue sample (0.90 cm of subcutaneous fat), 4) gel plus a gel pad and a pig tissue sample (1.8 cm of subcutaneous fat), 5) gel plus thin pig tissue sample, and 6) gel plus thick pig tissue sample. Each interposed material combination was tested at the intensities (W/cm^2) as follows: 0.10, 0.25, 0.50, 1.00, 1.50, and 2.50.

Results: The gel pad proved to be an efficient couplant in the delivery of high-frequency acoustic energy. Using ultrasound gel as the base line (100% transmissivity) it was concluded that the gel pad transmitted more acoustic energy at every intensity except at 0.1 W/cm^2. The gel pad used with the two thicknesses of subcutaneous fat gave comparable results. Gel used with the two thicknesses of subcutaneous fat yielded results that warrant further investigation.

Conclusions: I believe gel pads are a practical choice for clinical applications of ultrasound over uneven surfaces. The reusable gel pads offer the clinician a convenient and reliable method for delivering ultrasound energy to the patient. I believe it is preferable to use the gel pad with ultrasound gel directly applied to the patient and at the sound head-gel pad interface as opposed to using the traditional water bath immersion method.

Key Words: ultrasound, transmissivity, gel pad

There are many couplants commercially available for ultrasound transmission.[1] A couplant or coupling agent is a medium used to transfer sound waves.[12] The main function of the coupling agent is to provide high transmission with low absorption of ultrasound energy. Any ultrasound energy absorbed by the coupling agent is said to be attenuated.[1] Characteristics of coupling agents include viscosity, ease of use, salt content, cost, and the ability to exclude air.[9,13]

The exclusion of air is important due to the reflection of the sound waves that may occur at couplant-tissue interfaces.[13] The viscosity determines how much of the couplant will be needed per treatment. The ease of use of the couplant refers to the relative lubrication provided by the coupling agent.[12,13] A low salt content couplant minimizes salt buildup on the sound head over time, thus decreasing the potential of damage to the crystal housed in the transducer.[9] Lastly, cost of the couplant may be the determining factor for what is used in the clinic.[12,13]

Some coupling agents, such as topical gel, have been demonstrated to transmit sound energy efficiently.[1,6,11,12] Others, like water, are inefficient.[4,5] Recently, gel pads have been made commercially available. These pads function as a coupling agent by themselves or when used with a topical gel.[8] The purpose of the gel pad is to provide patient comfort and protection over bony protuberances or irregular surfaces.[8] Because topical gel has been proven to transmit more ultrasound energy than glycerin, mineral oil, or water,[1,4,5,6,11,12] the gel pad, theoretically, should exhibit the same quality as topical gel. This may not be the case. The purpose of this in vitro study was to determine the effectiveness of a commercial gel pad in delivering sound energy to pig tissue.

At the time of this study **Brian Klucinec** was an undergraduate at Slippery Rock University, Slippery Rock, PA 16057. Currently, Mr. Klucinec is a graduate student at the Krannert School of Physical Therapy, University of Indianapolis, 1400 East Hanna Avenue, Indianapolis, IN 46227. This article earned Mr. Klucinec recognition as first runner-up in the 18th Annual Student Writing Contest.

MATERIALS AND METHODS

Instrumentation

A 1-MHz Intelect 225P ultrasound unit (Chattanooga Corp., Chattanooga, TN), with a 5.0 cm^2 sound head and an effective radiating area (ERA) of 4.0 cm^2, was used to deliver acoustic energy at selected intensities. The unit was calibrated before the first trial. A detachable transducer having the same ERA was utilized to receive the signal sent by the 1-MHz unit by patching the coaxial cable into an oscilloscope via a bus net connector. For recording purposes, a 100 Ms/sec 450 Gould digital storage oscilloscope (Gould Inc., Ilford, United Kingdom) was used to record peak-to-peak values at various intensities. For accuracy and consistency, a two-dimensional level was used to fix all movable instruments.

Procedure

To perform the pilot trials and experiment, a platform apparatus (Fig 1) was constructed out of steel, aluminum, and plexiglass. The foundation consisted of a 50-lb aluminum

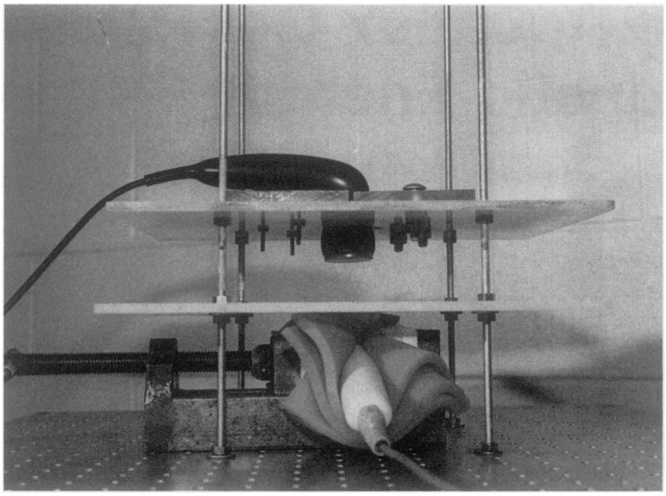

Fig 1. The constructed apparatus.

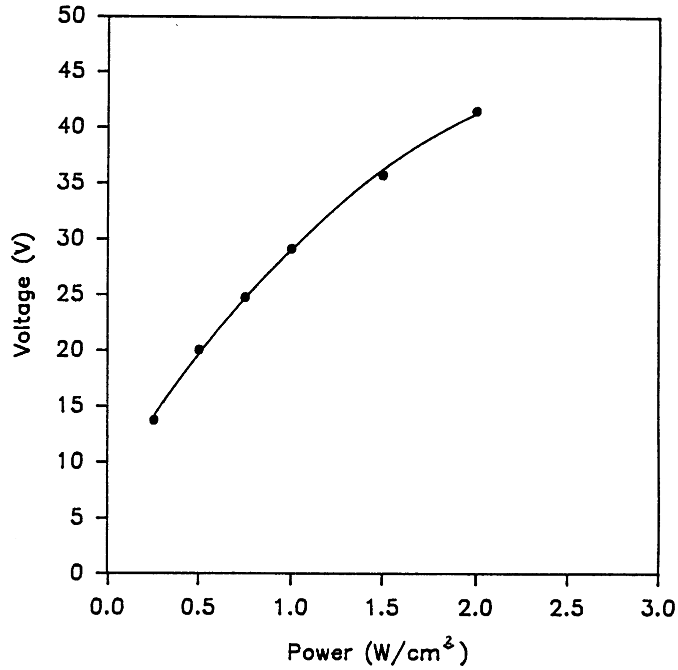

Fig 2. Mean voltage output of the three pilot trials at selected intensities.

block with 1/4-inch holes drilled into it at 1-inch intervals. Four 1/4-inch rods were fixed in these holes 7 inches apart and secured by nuts with washers. Two pieces of plexiglass were made to slide vertically along these rods creating two horizontal platforms. In the center of the plexiglass platforms, holes were drilled to house the transducer heads. The bottom piece of plexiglass was fixed and housed the receiving sound head. The top piece of plexiglass was movable and housed the transmitting transducer. The detachable sound head was fixed in a hand-tightened vise surrounded by foam to protect the transducer. The surface of the detachable sound head was then made level and flush with the bottom piece of plexiglass.

The transmitting transducer was placed in the hole drilled in the top piece of plexiglass allowing the ERA to be parallel to the ERA of the receiving sound head. The transmitting sound head was made parallel to the receiving sound head by viewing the ERA through a convex mirror and using a level. The transmitting sound head was then fixed to the top plate by creating a "harness" for the transducer neck. This harness was made from two pieces of thicker plexiglass. One piece was fixed with bolts while the other was allowed to move by slots to adjust for tightness. Fixation of the transmitting transducer created only one movable piece throughout the duration of the experiment.

Pilot trials were conducted to test the accuracy of the apparatus (Fig 2). The pilot trials were conducted with the use of an Aquaflex Ultrasound Gel Pad (Parker Laboratory, Orange, NJ) and Liqua Sonic Ultrasound Gel (Chester Laboratory, Erlanger, KY). Each trial was conducted by placing ultrasound gel at each interface to prevent reflection of the acoustic energy. The transmitting transducer was then lowered until it reached contact with the gel pad. The movable piece, supported by four nuts and washers, was made parallel to the bottom piece using a two-dimensional level. To record the data, the ultrasound unit was turned on, set at 100% continuous, then manually adjusted to the desired intensity. The peak-to-peak voltage was recorded immediately. Three pilot trials were completed. After each trial, the constructed apparatus was disassembled, cleaned, and reassembled.

During this project, ultrasound transmission was measured at six intensities with six different material combinations interposed between the sound head. The six materials were: 1) ultrasound gel, 2) gel plus a gel pad, 3) gel plus a gel pad and a pig tissue sample (0.90 cm of subcutaneous fat), 4) gel plus a gel pad and a pig tissue sample (1.8 cm of subcutaneous fat), 5) gel plus the thin pig tissue sample, and 6) gel plus the thick pig tissue sample.

Pig tissue was selected because the ratio of skin, fat, muscle, and bone is similar to that of humans.[7] The first tissue sample had the dimensions of 4 inches by 4.75 inches with 0.90 cm of subcutaneous fat. The second tissue sample had dimensions of 4 inches by 4.50 inches with 1.8 cm of subcutaneous fat. The tissue was obtained fresh, then frozen, and finally thawed before the testing. The tissue was thawed in lukewarm water approximately 20 hours in advance and then allowed to warm to room temperature. Room temperature was recorded by a digital thermoprobe at 72.5° F. Because the two tissue samples differed in the amount of hair on the skin, one sample was trimmed to be visibly similar to the other sample. This was done knowing that the tissue with more hair would have attenuated more acoustic energy.[2,3] Before beginning each trial, care was taken to cleanse the plexiglass, transducers, and tissue samples with tap water. This was done to free the instruments and tissue samples of debris that might have accumulated.

Three trials were conducted for each of the six interposed materials. Care was taken to place an adequate amount of ultrasound gel at each interface to prevent reflection. Care was also taken to eliminate any air trapped at each interface by firmly pressing down on the tissue and gel pad. For each material trial set up, the movable segment of the apparatus was lowered until contact was made with the tissue, gel pad, or gel. The segment was then made parallel to the fixed segment by

Table 1. Trial 1 Ultrasound Interposed Materials with Peak-to-Peak Voltages Read at Specified Intensity Levels (W/cm²)

	Intensities					
Interposed materials	0.10	0.25	0.50	1.00	1.50	2.50
Gel	1.66	7.33	10.20	16.00	20.20	25.30
Gel + pad	1.16	11.50	12.30	19.70	26.30	27.30
Gel + pad + thin tissue	1.16	2.66	8.33	17.70	12.20	20.00
Gel + pad + thick tissue	1.16	5.50	7.33	11.70	18.50	24.50
Gel + thin tissue	1.00	4.50	6.00	8.66	10.30	12.70
Gel + thick tissue	2.16	10.00	14.80	21.70	27.00	36.80

adjusting the nuts under the movable segment and checked with the two-dimensional level.

Ultrasound transmission was read at six selected intensities during each trial. Starting at the lowest intensity, the ultrasound unit was turned on and manually adjusted to the desired intensity. The peak-to-peak voltage of the sine wave was recorded immediately. The ultrasound unit was then shut off and the intensity turned down. Each interposed material was tested in the same sequence of intensities. The interposed material was not subjected to continuous ultrasound exposure because increasing thermal responses reduces the impedance of the tissue.[10]

After testing each material at each intensity, both transducers and surrounding ultrasound gel were examined for debris that might have interfered with the test. Between each trial, new ultrasound gel was placed at the interfaces to ensure an adequate interface.

RESULTS

Figure 2 represents the mean voltage output of pilot trials 1, 2, and 3 at specified intensity levels. The data recorded for each pilot trial were similar. The repeatability of peak-to-peak values for each pilot trial set the foundation for the following trials.

Peak-to-peak voltages for each interposed material at specified intensity levels during the three trials are presented in Tables 1, 2, and 3, respectively. The average peak-to-peak voltages from the three trials are presented in Table 4. The gel pad proved to be an efficient couplant in transmitting acoustic energy (Fig 3). Using ultrasound gel as a base line (100% transmissivity), as much as 27% more acoustic energy was transmitted through the gel pad. The gel pad transmitted more acoustic energy at every intensity except at 0.10 W/cm². The gel pad used with the two thicknesses of subcutaneous fat gave comparable results (Fig 4). This finding is in agreement with a recent report[2] that ultrasound does penetrate through subcutaneous fat.

The trials using ultrasound gel with the thin and thick tissues produced perplexing results. The peak-to-peak voltages of the ultrasound gel and the thick tissue sample were more than double compared with the ultrasound gel used with the thin sample (Fig 5).

DISCUSSION

The gel pad was an efficient transmitter of acoustic energy. The gel pad interposed with the two thicknesses of tissue produced similar results. The tissue samples differed only in the thickness of subcutaneous fat.

There was a discrepancy when the gel pad was removed and both thicknesses of tissue were subjected to just ultrasound gel as the conducting medium. The ultrasound gel used with the thick tissue produced more than twice the voltage output compared with the interposed material of gel and thin tissue. There may be several explanations for this finding. Pressure variations may have been a contributor to changes in transmissivity throughout the experiment.[12] In applying pressure to the tissue, a quantity of the ultrasound gel may have been dispersed, leaving only a thin film of gel. The thin layer of gel coupled with the thicker subcutaneous fat sample may have aided in the conduction of the acoustic energy, leading to increased transmission of acoustic energy and consequently increased voltage readings. However, the magnitude of difference in acoustic energy transmission between the two tissues plus ultrasound gel for all three trials suggests that pressure differences may not have been the cause. This study was limited to a 1-MHz ultrasound unit; other frequencies may yield different results. Lastly, the BNR (beam nonuniformity ratio) of the 1-MHz ultrasound unit was 3.5 to 4.0:1. The poor crystal quality may have caused the vast range in the voltage readings.

Table 2. Trial 2 Ultrasound Interposed Materials with Peak-to-Peak Voltages Read at Specified Intensity Levels (W/cm²)

	Intensities					
Interposed materials	0.10	0.25	0.50	1.00	1.50	2.50
Gel	1.83	8.33	11.80	16.70	20.00	25.80
Gel + pad	1.33	9.66	13.80	19.30	24.30	30.50
Gel + pad + thin tissue	1.16	3.66	7.00	14.00	15.50	21.20
Gel + pad + thick tissue	1.16	4.66	6.66	14.00	17.20	22.30
Gel + thin tissue	1.33	4.33	6.16	9.00	11.50	15.00
Gel + thick tissue	2.00	9.50	14.20	20.30	25.30	34.50

Table 3. Trial 3 Ultrasound Interposed Materials with Peak-to-Peak Voltages Read at Specified Intensity Levels (W/cm²)

	Intensities					
Interposed materials	0.10	0.25	0.50	1.00	1.50	2.50
Gel	2.00	9.00	12.80	18.00	22.00	28.00
Gel + pad	1.16	10.20	12.80	21.20	26.20	32.50
Gel + pad + thin tissue	1.16	4.33	6.66	13.00	16.50	21.00
Gel + pad + thick tissue	1.00	5.83	8.33	12.80	13.70	25.50
Gel + thin tissue	1.50	5.66	8.00	12.30	14.80	17.20
Gel + thick tissue	1.50	9.83	13.00	19.20	22.30	34.00

Table 4. Ultrasound Interposed Materials with Average Peak-to-Peak Voltages from Trials One, Two, and Three Read at Specified Intensity Levels (W/cm²)

	Intensities					
Interposed materials	0.10	0.25	0.50	1.00	1.50	2.50
Gel	1.83	8.22	11.60	16.90	20.73	26.37
Gel + pad	1.38	10.45	12.97	20.10	25.60	30.10
Gel + pad + thin tissue	1.16	3.55	7.33	14.90	14.73	20.73
Gel + pad + thick tissue	1.12	5.33	7.44	12.83	16.47	24.10
Gel + thin tissue	1.28	4.83	6.72	9.99	12.20	14.97
Gel + thick tissue	1.89	9.78	14.00	20.40	24.87	35.00

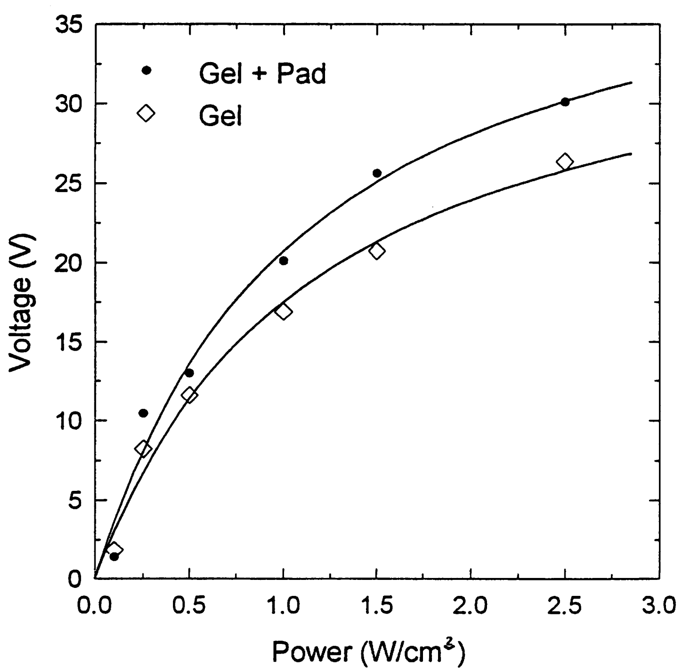

Fig 3. Comparison of gel and gel + pad conditions.

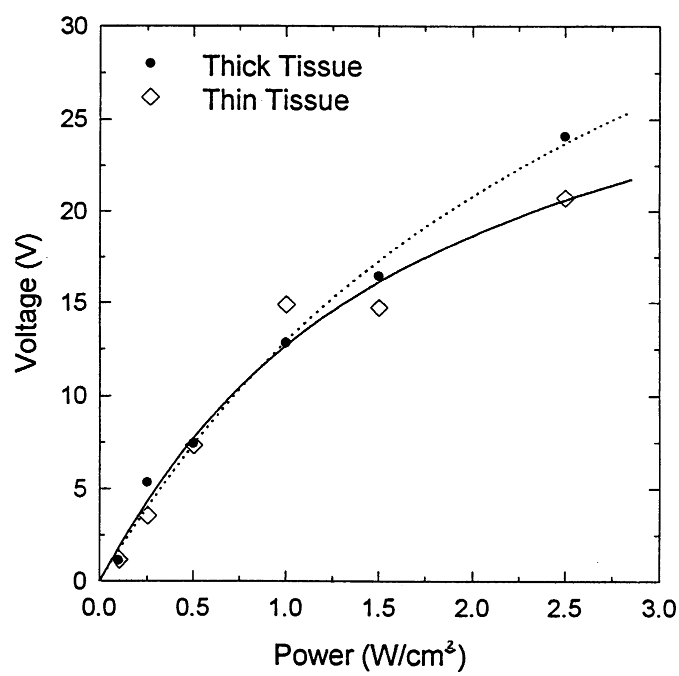

Fig 4. Comparison of gel + pad + thin tissue and gel + pad + thick tissue conditions.

I believe that gel pads are a practical choice for clinical applications of ultrasound over uneven surfaces. The causes of differing results when ultrasound gel was used with thin and thick tissues are not apparent and warrant further investigation. Until gel pads became commercially available, the traditional clinic method of ultrasound application to bony areas was done via water bath. Forrest and Rosen[4,5] have demonstrated that water baths are a relatively inefficient method of delivering high-frequency acoustic energy. Ultrasound application under water fails to increase the temperature of the target tissue to a therapeutic level. I believe gel pads are the couplant of choice for ultrasound treatments over bony prominences. My findings suggest that gel pads are an efficient couplant in the delivery of high-frequency acoustic energy.

The reusable gel pads offer the clinician a convenient and reliable method for delivering ultrasound energy to the patient. When treating soft tissue around bony prominences, it is preferable to use the gel pad with ultrasound gel directly applied to the patient and at the sound head-gel pad interface as opposed to using the traditional water bath immersion method.

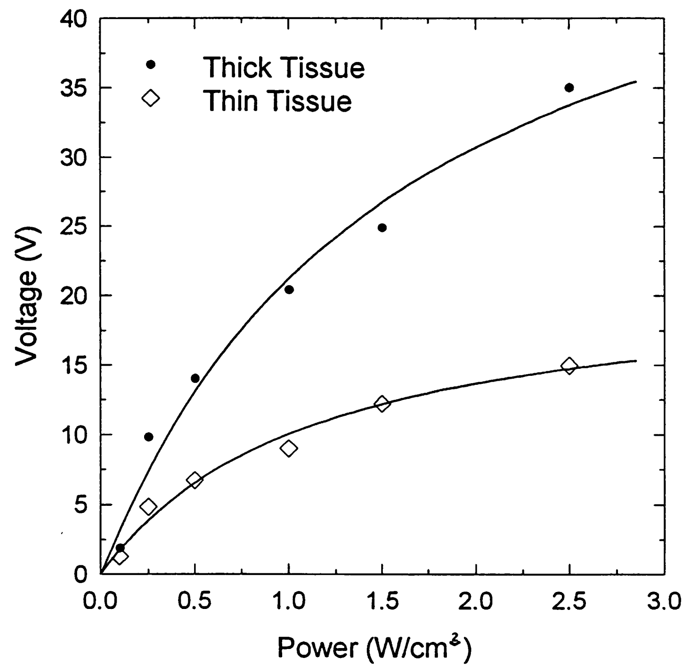

Fig 5. Comparison of gel + thin tissue and gel + thick tissue conditions.

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